ADVISOR, Advanced Vehicle Simulator, New Opportunities for Screening Advanced Components
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ADVISOR is a flexible, accurate Advanced Vehicle SimulatOR, developed at the Department of Energy's National Renewable Energy laboratory. It predicts fuel economy, performance, and emissions of hybrid-electric, conventional, and electric vehicles, and can be used to size components and devise control strategies for advanced vehicles. To date, it has been used to support the DOE Hybrid Vehicle contracts, the PNGV Systems Analysis effort, and other analysis work at the DOE and other National Labs.

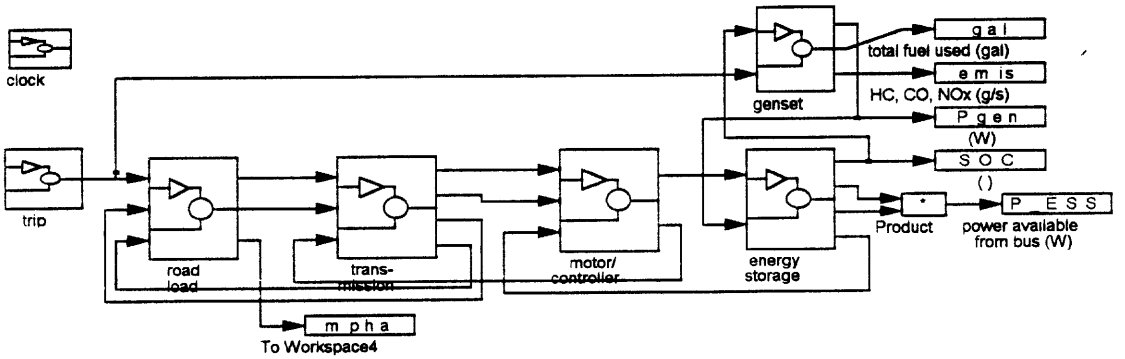

Figure 1. Top level of ADVISOR's series HEV model

The most significant difference between and ADVISOR and other, previously developed, public-domain vehicle prediction tools is its flexibility. ADVISOR was developed in the MATLAB®/Simulink® programming environment. This proprietary dynamic simulation environment is used by engineers throughout industry to simulate complex system behavior, and is popular for its ease-of-use and power. The development environment is graphical and object-oriented, facilitating rapid model development and modification. Additionally, no traditional "lines" of code are required to model complex systems in Simulink, making it easier to read and understand than traditional C and Fortran source code.

ADVISOR's flexibility allows complex control strategies, rather than simple "thermostat" approaches, to be developed and analyzed in the context of a particular vehicle. Likewise, complex component models may be included in ADVISOR, including equivalent-circuit models of batteries, ultracapacitors, etc. Engineers at Chrysler Corp. have made significant use of such detailed models in ADVISOR. The modularity of ADVISOR's approach allows each component to modeled at a different level of complexity, if so desired.

ADVISOR, by virtue of being developed in Simulink, is integrated with packaged optimization subroutines. The application of these routines to ADVISOR's detailed vehicle models allows analysts to optimally size, combine, and control the different advanced vehicle components. The optimal solution ADVISOR develops may be constrained by requirements on vehicle fuel economy, performance, and/or component variables such as maximum rate of power change. These real-life constraints result in a solution that more closely conforms to reality and takes into account the limitations and preferred operating modes of all components in the vehicle.

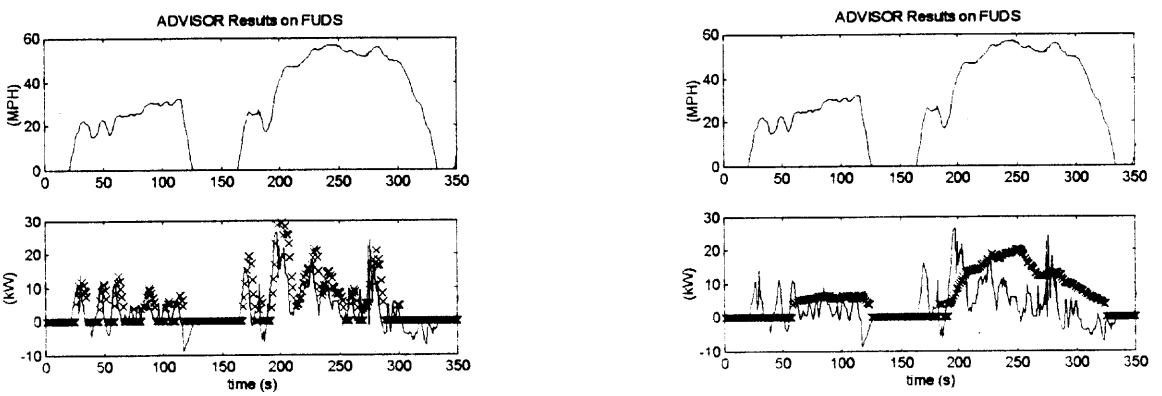

Figure 2. Series HEVs on the FUDS: HPU and tractive motor power for two control strategies

The graphs above illustrate the power of ADVISOR's built-in optimizer. In each case, the series-configured hybrid vehicle's fuel economy on the Combined Federal Cycle is maximized by modifying the hybrid control strategy the vehicle uses. In the left figure, the hybrid power unit (HPU) power, indicated by the Xs, closely follows the power delivered to the traction motor, indicated by the solid line. This vehicle's DI diesel HPU happens to have a reasonably broad "sweet spot", in which the thermal efficiency is close to its peak value, and it has the ability to rapidly follow power transients. The battery pack in this case is not particularly efficient. So the optimizer has determined that the best approach is for the HPU to provide the power required for propulsion when it can, and for the electric drivetrain to make up extra power where needed.

In the right figure, the gas turbine HPU power varies slowly, tracking the average input power to the traction motor, while the battery pack delivers and accepts power transients. In this case, the HPU's SFC (specific fuel consumption) map has a smaller sweet spot, and more importantly, this gas turbine incurs significant fuel use penalties during transients. Also, the battery pack in this case is more efficient than in the former case. The optimizer has chosen the best trade-off between allowing the HPU to experience power transients and having the battery pack be charged and discharged.

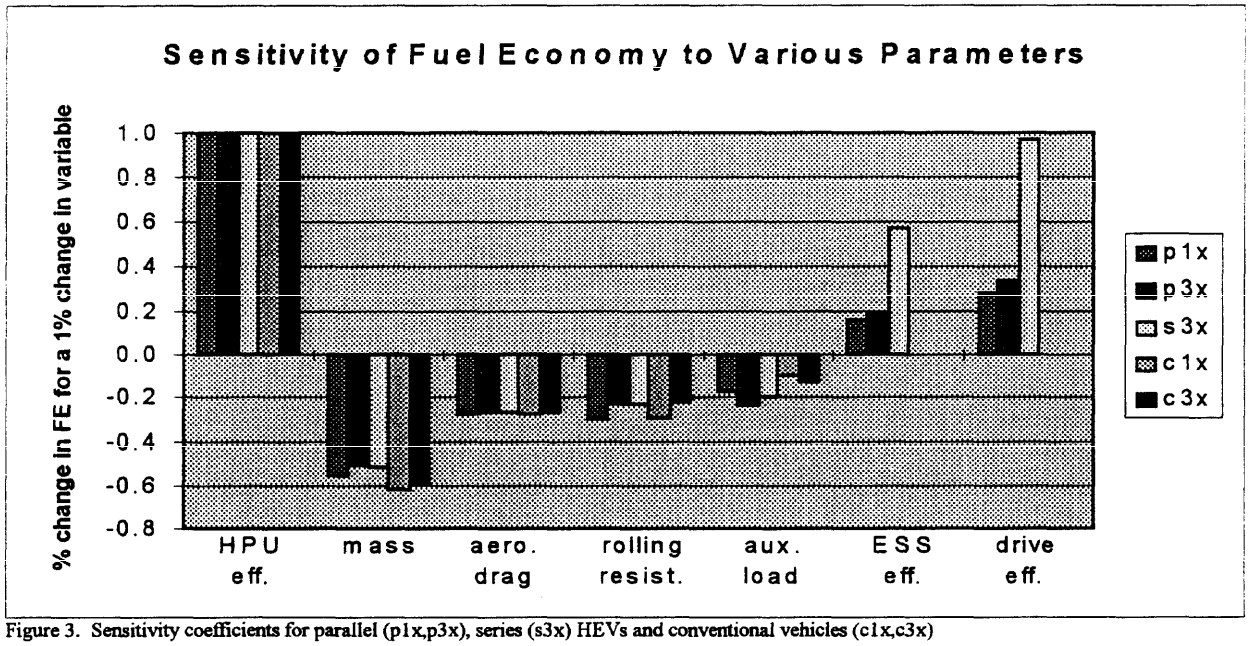

Figure 3. Sensitivity coefficients for parallel (p1x,p3x), series (s3x) HEVs and conventional vehicles (c1x,c3x)

ADVISOR is particularly well-suited to parametric and sensitivity studies, being essentially a fast-executing MATLAB subroutine which is easily called from simple MATLAB scripts. The above graph indicates the sensitivity of various vehicles' fuel economy to a number of vehicle and component design parameters. In this example, lightweight, advanced vehicles (c3x,p3x,s3x) and off-the-shelf-technology vehicles (c1x,p1x) are analyzed. Note that the fuel economy effect of changes in HPU efficiency, vehicle mass, aerodynamic drag, rolling resistance, and auxiliary loads are nearly identical for all vehicles. The graphs indicate that the series design is much more sensitive to changes in energy storage system (ESS) and electric drive (including the motor, controller, and transmission) efficiency than are the parallel designs considered here. All tractive power and energy comes via the motor, with much of it supplied by the ESS, in the series design, while the parallel designs get most of their tractive energy directly from the HPU; thus, the difference in sensitivities. For a more detailed discussion of this analysis see Wipke and Cuddy, "Using an Advanced Vehicle Simulator (ADVISOR) to Guide Hybrid Vehicle Propulsion System Development," presented at NESEA's 1996 Sustainable Transportation Conference.

In summary, ADVISOR is an extremely flexible, powerful vehicle performance simulator developed at the National Renewable Energy Laboratory in 1994, with funding from the Department of Energy. ADVISOR is integrated with automatization and optimization tools which facilitate study of the many-dimensional advanced vehicle design space. ADVISOR has been correlated with credible vehicle models, and hardware testing for actual validation is ongoing.